Carbon Nanotube Infused Launch Vehicle Structures

Completed Technology Project (2017 - 2019)

Project Introduction

For the past 5 years Orbital ATK has been investing in, prototyping, and testing carbon nanotube infused composite structures to evaluate their impact on launch vehicle structural damping. Improvements to structural damping would be revolutionary to launch vehicle design. For any vehicle a significant portion of design, material, and integration efforts center on mitigating the severe dynamic environments seen during flight. This includes launch acoustics, random vibration, sinusoidal vibration, and shock. Acoustics are driven by high frequency pressure fluctuations associated with motor firing or the launch vehicle quickly passing through the atmosphere. This induces responses and stress in structures and components. During launch random vibration from aero-acoustics also induces stresses to hardware (e.g. components, as pieces, move relative to each other) risking failure both due to magnitude and fatigue. Sinusoidal vibration, usually (but not always) related to motor chamber pressure resonance during burn, can couple with a component or structure’s natural frequency –magnifying the vibration and posing significant structural and hardware risk. Lastly, short high magnitude shock events also occur at the ignition of each motor stage and at each stage’s pyrotechnic separation event. Shock poses significant technical risk and is a common driver for launch vehicle design requirements. Testing to date by the Orbital ATK Launch Vehicle Division (LVD) has shown that by infusing CNT into composite we can improve the structural damping by a factor of 2x. Improved damping attenuates launch dynamic environments which leads to cascading benefits if CNT’s are infused into all primary and secondary structures. The improved damping lowers transient dynamic loads in primary structures and reduces secondary structure dynamic response. This allows reduction of primary and secondary structural mass. Moreover shock and random vibration are reduced into components which may allow for the elimination of hardware isolation systems. With no isolation required on hundreds of components (including the payload), a significant amount of “parasitic mass” can be eliminated. The significant reduction in part quantity and design complexity produces cascading material, design, test, and integration cost savings and expedites program schedules. A case study on Orbital ATK launch vehicles shows elimination of parasitic mass enabled through CNT utilization could increase payload mass to orbit by >10% and reduce launch vehicle cost by >15%. Dynamic loads and environments into the spacecraft are also decreased—enabling reduction in payload structural mass, associated propellant mass, and reduce spacecraft test environments. CNT infused launch vehicle structures are at a tipping point enabling breakthrough improvement in structural damping. CNT’s efficacy improving damping has been shown at a coupon level in a lab environment (TRL 4). A two phased approach is proposed to mature this technology further. Phase I advances TRL to level 5 by building subsystem level prototypes and executing flight-like testing. CNT infused composites will be prototyped and tested in two independent configurations: CNT sheets interstitially layered in pre-impregnated (pre-preg) composite, and chopped CNT’s dispersed into

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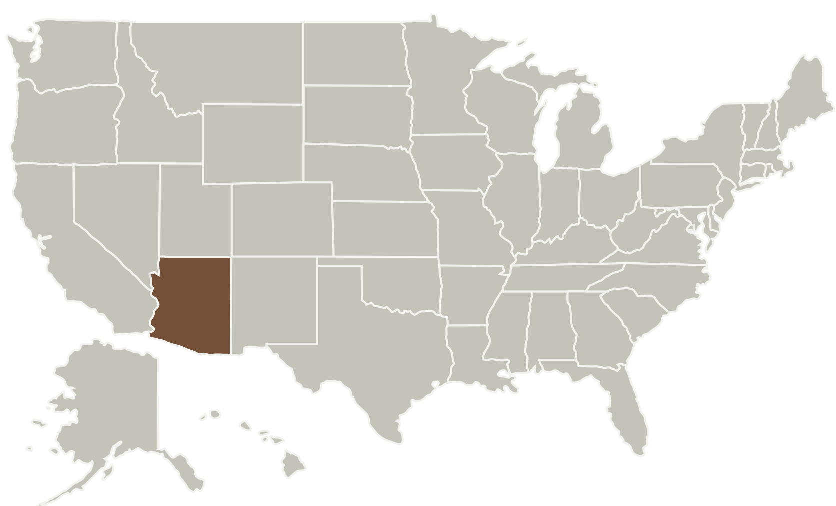
composite. Phase II advances TRL to level 6 by building full-scale flight structures and completing end to end testing (ground and/or flight tests). Flight structures include a CNT sounding rocket interstage and a palletized CNT lattice bulkhead for a major launch vehicle. Orbital ATK is the prime contractor for the NASA Sounding Rocket Operations Contract (NSROC) program. Zero-cost rideshare opportunities to fly the CNT interstage will be pursued on best effort basis through the NSROC program. Results of this two-phased approach will demonstrate the safety, robustness, and cascading benefits of CNT technology in launch vehicles.

Anticipated Benefits

Results of this two-phased approach will demonstrate the safety, robustness, and cascading benefits of CNT (carbon nanotube) technology in launch vehicles. These solicitations increase focus on collaborations with the commercial space sector that not only leverage emerging markets and capabilities to meet NASA's strategic goals, but also focus on industry needs. NASA's investments in industry partnerships can accelerate the availability of, and reduce costs for the development and infusion of, these emerging space system capabilities. While developing the technology to enable NASA's next generation of science and human exploration missions, we will grow the economy and strengthen the nation's economic competitiveness.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Northrop Grumman Systems Corporation

Responsible Program:

Flight Opportunities

Project Management

Program Director:

Christopher E Baker

Program Manager:

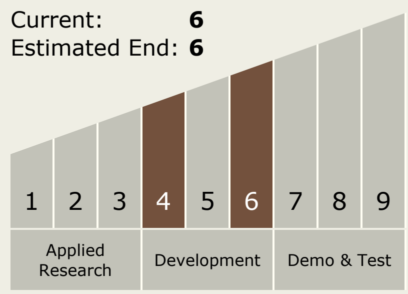
John W Kelly

Principal Investigator:

Trevor J Pirtle

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



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Organizations Performing Work	Role	Type	Location
Northrop Grumman Systems Corporation	Lead Organization	Industry	Falls Church, Virginia

Primary U.S. Work Locations
Arizona

Project Transitions

June 2017: Project Start

August 2019: Closed out

Closeout Summary: Incorporation of advanced materials for dampening into flight structures to reduce dynamic loads during flight. Building subscale and full-scale flight structures. This technology has potential to increase the payload capability and reduce costs for launch vehicles. The designs were successfully tested and the final test report was completed in August of 2019.

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Target Destination

Earth